

May 28, 1963

R. A. BOROWIEC ET AL
ELECTRONIC ASSEMBLY PACKAGING

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3 Sheets-Sheet 1

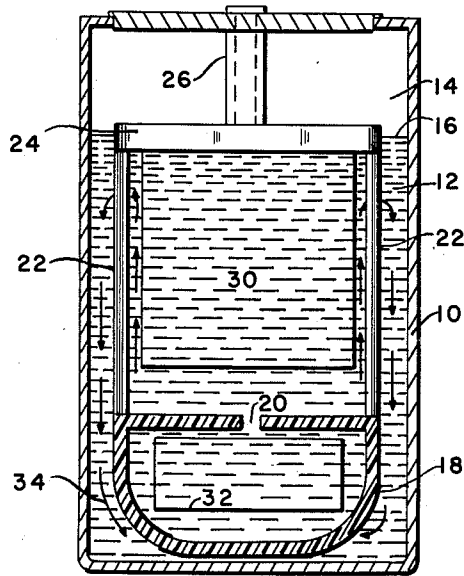


FIG. 1

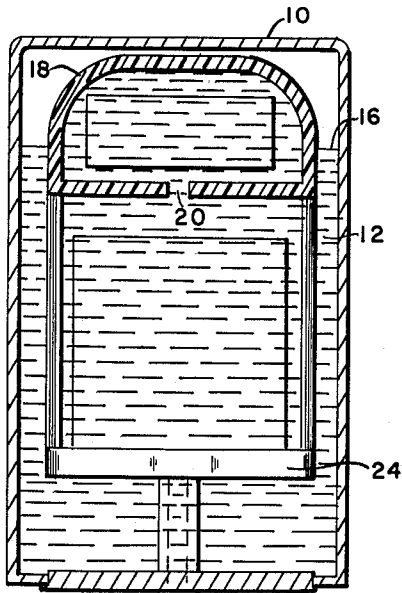


FIG. 1A

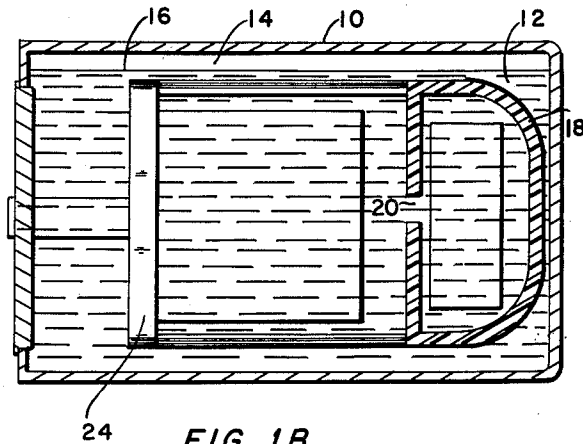


FIG. 1B

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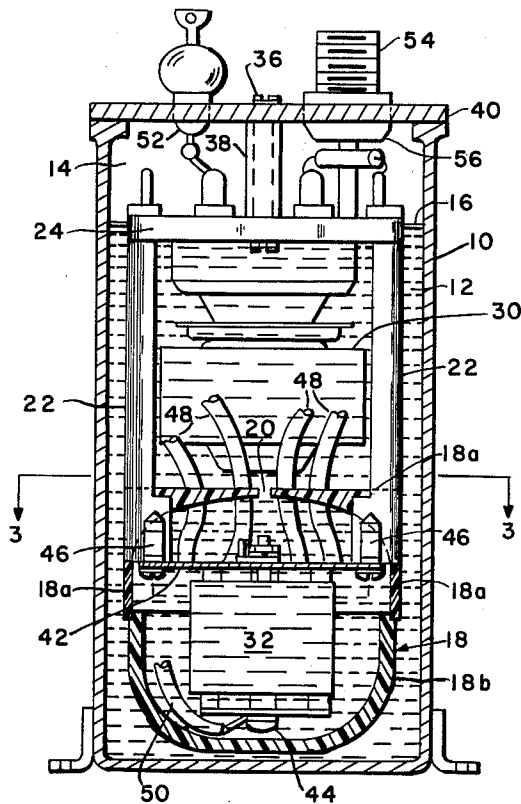


FIG. 2

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3 Sheets-Sheet 3

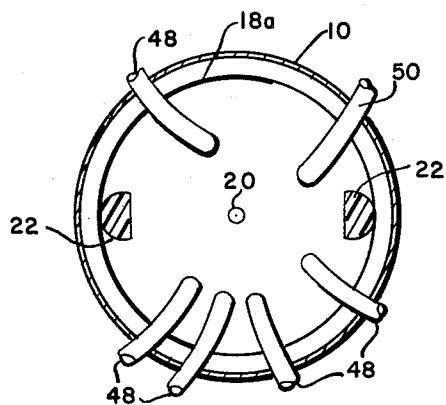


FIG. 3

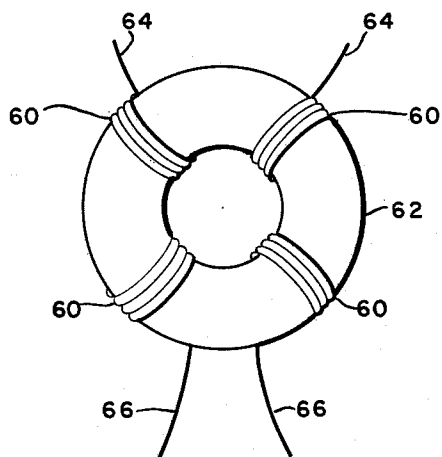


FIG. 4

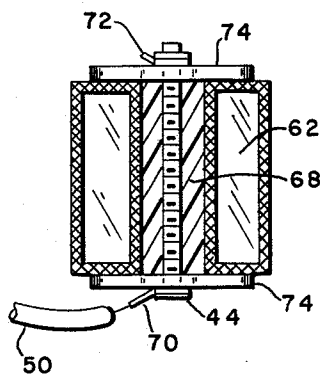


FIG. 5

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ELECTRONIC ASSEMBLY PACKAGING

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8 Claims. (Cl. 317-100)

This invention relates to electronic assemblies, and is more particularly concerned with the compact packaging of a liquid cooled high voltage assembly.

In ordinary high voltage electronic equipment, such as a television receiver, little special design effort is necessary to provide the requisite transfer of heat, since there is normally sufficient space around the tubes and other heat-dissipating components that adequate cooling is provided by natural convection of air over the assembly. Under conditions of ample space and normal ambient temperatures, high voltage transformers, for example, may be mounted separately, connected to associated tubes by leads, and coated with a solid insulating material to suppress corona and prevent breakdown which might be caused by humidity. On the other hand, high voltage electronic equipment intended for operation at elevated temperature, high humidity, and under severe shock and vibration conditions may require immersion of tubes in a liquid coolant, and immersion of transformers in an insulating liquid, such as oil, to suppress corona and prevent breakdown between windings of the transformer. A number of assembly variations have heretofore been employed to provide such insulation and cooling in severe operational environments. In one assembly with which applicants are familiar, the tube is air cooled, the transformer is immersed in oil, and insulated leads connect the transformer to the tube socket. A known improvement to this general approach has the transformer and tube socket combined in a single structure, with the transformer and all leads and connections to the socket completely immersed in oil. In the latter structure, however, the electrical grade oil normally used for this application expands approximately 15% in volume upon raising the external ambient temperature from room temperature to 300° F., sufficient to deform or possibly fracture the structure. Conversely, in cooling from room temperature to -65° F. this grade of oil contracts approximately 15%, and may expose the connections to cause high voltage breakdown. Consequently, a completely oil-filled transformer-socket structure is useful only in applications in which narrow temperature excursions are encountered, or must be provided with bellows and/or diaphragms to compensate for the expansion and contraction of the oil with temperature. In assemblies in which only the transformer is immersed in oil, and contemplated for use in a fixed position and at atmospheric pressure, oil contraction and expansion is conventionally provided by leaving an air gap at the top of the package, the container being sufficiently large, and containing sufficient oil that the transformer is not exposed by contraction of the oil at low temperatures. In some applications it has even been possible to combine the transformer and tube in a common oil immersed package, but here again a bellows and/or diaphragm has been necessary to solve the expansion and contraction problem.

These packaging techniques are not satisfactory for airborne electronic equipment, however, where space and weight are prime factors and there are the additional environmental factors of attitude and air pressure to be considered. For instance, a sealed assembly comprising a tube, high voltage transformer and socket completely immersed in a liquid coolant and/or dielectric would be

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too bulky and complicated for airborne use because of the required bellows and/or diaphragms. In any event, in most cases a transformer of conventional design would be too large as compared to the tube to be economically assembled in the same package with the tube. As a compromise, the tube is normally enclosed in a sealed, oil-filled can, and the transformer placed in a separate epoxy-sealed container. Heavy insulation on the transformer windings is necessary for high-altitude use, which dictates a transformer core of large diameter, which further adds to the bulk of the assembly. The separation of the tube from the transformer necessitates the use of connecting wires, which have been found to introduce stray inductance and capacitance which deleteriously affect the operation of the circuit and radiate electrical noise to nearby equipment.

With an appreciation of the shortcomings of available packaging techniques and the problems attendant the cooling and insulation of airborne electronic equipment, applicants have as a primary object of the present invention to provide a compact high-voltage tube and transformer assembly in which a safe level of insulating liquid is maintained regardless of attitude and temperature.

A general object of the invention is to provide an improved package for high-voltage electronic circuitry.

Another object of the invention is to provide a high voltage pulse amplifier package of minimum weight and volume which will operate satisfactorily in airborne equipment under severe environmental conditions.

Still another object of the invention is to provide a package for a tube and transformer assembly, immersed in a liquid coolant and dielectric, wherein the transformer is protected from exposure to air regardless of attitude and temperature.

A further object of the invention is to provide a single compact assembly of a high voltage tube and transformer immersed in a liquid coolant and dielectric.

Another object of the invention is to provide a tube and transformer assembly whose electrical characteristics are consistent from unit to unit.

Briefly, the foregoing objects are achieved by a packaging arrangement for the electronic components which at all times, and in all positions, insures complete immersion in a dielectric liquid of high voltage components, and also provides convection cooling of heat-dissipating but lower voltage components. In its broadest sense, the package according to the invention includes a sealed outer container, and an inner container or shell supported within the outer container. The inner container is also completely sealed, except for a small vent hole in a selected wall thereof. The inner container is completely filled with a suitable liquid dielectric so as to be completely free of air, and the outer container is partially filled to allow room for expansion with increased temperature. The vent hole permits expansion of the fluid in the inner container by discharging it into the outer container. The outer container is filled with liquid to a level which insures that the vent hole is always immersed in liquid, regardless of the position or attitude of the package, and regardless, also, of expansion or contraction of the liquid with changes in temperature over a wide range. Thus, the inner shell is always completely filled with dielectric fluid and free of air, thereby insuring protection against breakdown of high voltage apparatus contained therein.

In the packaging of the pulse amplifier circuit to be described, the inner container is formed of insulating material and has a miniaturized high voltage transformer enclosed therein. The dielectric liquid in the shell acts as a corona suppressor and as a secondary dielectric between windings. An electronic tube suitable for use with

the transformer is supported on a socket within the outer container, the level of the liquid being such as to completely surround the tube in most positions of the package and under most temperature conditions. The dielectric liquid flows around the tube by convection to act as a coolant therefor in addition to affording insulation. All connecting wires between the transformer and tube socket are enclosed within the outer container and are at most times immersed in the dielectric liquid, to thereby eliminate radiation from the tube and transformer and stabilize the inductance and capacitance between the leads.

The reduction in size of the pulse transformer to permit its enclosure in the inner shell is accomplished by reducing wire size, thickness of insulation, and concomitantly the core diameter. A polyester coating and tape are used for insulation, and the windings are divided into four compact coils located at 90° intervals about a toroidal core. The use of narrow gauge wire and the quadrature arrangement of the coils reduces the inter-winding and intra-winding capacities to a minimum. The polyester dielectric permits a separation of less than twenty thousandths of an inch between windings, thus reducing leakage inductance to a minimum while still maintaining a high voltage insulation between them.

Other objects, features and advantages of the invention and a better understanding of its construction and operation will be apparent from the following detailed description, taken in connection with the accompanying drawings, in which:

FIGS. 1, 1A and 1B are schematic cross-sectional views of the package according to the invention, in three different positions;

FIG. 2 is an elevation cross-section view of a transformer-tube package embodying the invention;

FIG. 3 is a cross-section view taken along line 3—3 of FIG. 2 showing the relative positions of the vent hole, leads, and standoff supports of the inner shell;

FIG. 4 is a diagrammatic plan view of the high-voltage transformer used in the assembly of FIG. 2; and

FIG. 5 is an elevation cross-section view of the high voltage transformer.

Referring to FIG. 1, the package according to the invention is schematically illustrated as comprising an outer cylindrical container or can 10 partially filled with a liquid coolant and dielectric 12 above which there is an air space 14, the level of the liquid being indicated by the liquid-air interface 16. Container 10 is completely sealed to be air tight. Mounted within the container 10 and completely immersed in the liquid 12 is an inner container or shell 18, preferably formed of insulating material when intended for high-voltage use. The shell 18 is completely filled with oil so as to be air-free, and is formed with a small vent hole 20 through which the liquid may flow. The shell 18 is suspended within the outer container by a pair of insulating standoff supports or rods 22, secured at their upper ends to an insulating support 24, which, in turn, is supported on the end wall of the container by an insulating support 26. By way of example, member 24 may be a socket for a high voltage tube, schematically shown at 30, with the space between the socket and the end wall employed for tube interwiring and the like. The shell 18 may enclose a component having critical voltage breakdown characteristics, such as a high voltage transformer, schematically represented at 32.

With this construction, the component 30 is cooled by natural convection circulation of the liquid coolant 12 (represented by arrows 34), is relatively independent of atmospheric conditions outside container 10, and requires no forced air cooling. Since the outer container is air-tight, the components within the container are unaffected by changes in external humidity and air pressure. The air space 14 is dimensioned to allow for the anticipated volumetric expansion of the liquid 12 due to

the heat produced by tube 20 and the maximum ambient temperature rise to be encountered. Since the air in this space is compressed with the expansion of the liquid, the air space is designed to limit such increase in air pressure to a safe level. As the three positions of the package illustrated in FIGS. 1, 1A and 1B demonstrate, the relationship of the liquid-air interface 16 to position of the vent hole 20 insures that inner shell 18 is always completely filled with liquid regardless of the attitude or temperature of container 10. Stated another way, regardless of expansion and contraction of the liquid, or changes in position of the outer container, the liquid-air interface 16 never goes below the vent hole 20 to allow entry of air. The insulating liquid 12 completely filling shell 18 at all times suppresses corona and serves as a dielectric between transformer windings, terminals, connections, or any other components in the shell which may be subject to breakdown. Thus, safe dielectric characteristics are maintained within shell 18 regardless of attitude or temperature.

FIG. 2 illustrates an assembly, embodying the invention, of a high voltage pulse amplifier circuit, intended for operation in airborne equipment under severe environments, consisting essentially of a 4X150 amplifier tube 30 and a miniaturized pulse transformer 32. The outer can 10, including its end walls are preferably formed of aluminum for weight reduction. A tube socket 24 is mounted within the can on a screw 36 and standoff support 38 secured to the top cover 40 of the can. More than one standoff support may be used if desired to give the necessary rigidity under anticipated vibration and shock conditions. The amplifier tube 30 is plugged into tube socket 24, and should anticipated environmental conditions require, may be additionally secured to the socket by soldering or other means. A shell 18, formed of insulating material, such as epoxy, is suspended from the tube socket 24 on a pair of standoff supports 22 formed of insulating material, with the shell in coaxial alignment with tube 30, socket 24 and cover plate 40. For ease of assembly, the shell 18 comprises a cylindrical epoxy base 18a formed with a concave interior, and an epoxy cup-shaped cover 18b. The standoff supports 22, which may be in the form of rods, are molded into the base 18a to provide a rigid, unitary sub-assembly.

Prior to placing the cover 18b on the base 18a, the pulse transformer 32 is mounted on an insulating terminal board 42, which may be formed of glass-epoxy, with an insulated metal screw 44, the terminal board, in turn, being mounted within base 18a and secured to the lower ends of standoff supports 22 by screws 46. The terminal board includes terminals, connections, and components (not shown) necessary to the operation of transformer 32. Electrical connection from the terminal board 42 to the tube socket is made by insulated leads 48 which extend through openings in base 18a. Another lead 50 connected to mounting screw 44 which, as will be explained hereinbelow, serves as a test winding for transformer 32, also passes through base 18a and is connected to a terminal at the top of container 10. Silicone rubber is used as insulation on the leads because of its property of swelling when immersed in silicone oil to insure a seal-fit of the leads with the feed-through holes in base 18a. When cover 18b is placed on base 18a and sealed with an airtight joint, the pulse transformer assembly is completely enclosed in shell 18. The interior of shell 18 communicates with the interior of container 10 through a small central vent 20 in base 18a. The location of this opening relative to the standoff supports 22 and leads 48 and 50 are clearly shown in FIG. 3.

The complete tube and shell assembly is immersed in electrical grade silicone oil 12 partially filling container 10, essentially to the level of tube socket 24, care being taken to remove all of the air from shell 18 and to completely fill it with oil before sealing cover 40 to the outer

container. Although the upper side of tube socket 24 carries terminals, connections and components necessary to the operation of the tube and transformer assembly, including wiring to the grids and filament of the tube, these are at relatively low potential making it unimportant whether they are immersed in oil or not. These windings are connected to one or more external connections (not shown) fitted in cover 40. However, others of the wiring and connections in this area, which is normally surrounded by air, do carry high voltages, and suitable provisions must be made to insulate them. For instance, the anode of the tube, at about 1,000 volts, is connected to a high voltage connector 52 sealed in the end plate 40, and properly spaced from other connections to prevent breakdown, even in air. The secondary windings of the pulse transformer, which may be at about 10,000 volts, are connected to high voltage connectors, one of which is shown at 54, and enclosed in a silastic rubber insulating compound 56 to prevent breakdown.

In order to assemble the pulse transformer within a shell 18 of reasonable size, applicants found it necessary to develop a transformer much smaller in size than was available. The reduction in transformer size was accomplished by reducing the diameter of the transformer core, which was made possible by using size #28 wire with very thin polyester insulation, and thin polyester tape for insulation between windings. The requisite high voltage is achieved in the small structure by dividing both the primary and secondary windings into four compact coils 60 located at 90° intervals about a toroid 62 as shown in FIG. 4. Briefly, the assembly of the transformer involves tapering the core completely with polyester tape, winding the primary coils, applying polyester tape over the primary windings, and then winding the secondary coils directly over the taped primary windings. The transformer has two secondary leads 64 and two primary leads 66. The small gauge wire and the quadrature arrangement of the coils reduces the inter-winding and intra-winding capacities to a minimum. The polyester dielectric permits a separation of less than twenty thousandths of an inch between windings, thus reducing leakage inductance to a minimum while still maintaining twelve kilovolts insulation between them.

Referring to FIG. 5, and to FIG. 2, the transformer is mounted to a chassis or terminal board by a mounting screw 44 which passes through the center of the toroidal core and is insulated therefrom and maintained centered by a drilled insulating rod 68. In addition to providing mechanical support for the transformer, the screw 44 functions as a half-turn test winding from which a signal bearing a fixed voltage ratio to the actual output of the transformer may be derived. A test signal lead 50 is connected to one end of screw 44 as by lug 70, and the other end of screw may be grounded, as by lug 72. The screw, insulating rod and toroid are held together to form a rigid assembly by a pair of insulating brackets 74 at either end of the core. This construction causes uniformity between transformers, since screw 44 cannot be displaced relative to the main windings 60, and mounting the transformer and adding the test winding are reduced to one simple operation.

Referring again to FIG. 2, the silicone oil 12 provides convection cooling for the amplifier tube and, within shell 18, acts as a corona suppressor and secondary dielectric between the transformer windings. Since the assembly is sealed, the components inside the container will be unaffected by changes in external humidity and air pressure. The air space above the oil allows for thermal expansion of the oil, within both the container and the shell. The location of the vent hole 20 in the shell 18 together with the surface tension of the oil preclude air from reaching the high voltage windings and connections of the transformer. That is, the assembly insures a safe level of insulating oil around the transformer regardless of the attitude and temperature of the assembly. Moreover, the

integration of the tube and transformer in one compact unit achieves a more nearly perfect electric circuit, contributing to more consistent pulse characteristics from unit to unit. In one airborne application, substitution of the single package of FIG. 2 for the heretofore available oil-immersed tube package and a separate epoxy-sealed transformer package, resulted in a reduction in volume by 30% and a reduction in weight of 40%.

From the foregoing, it will be seen that applicants have provided a compact tube and transformer assembly operable at any attitude and under severe environments. The transformer is enclosed in an air-free shell, the shell in turn being enclosed in an outer container. The shell is completely filled with oil and communicates through a vent with the interior of the outer container, which is only partially filled with oil to allow for expansion. The level of the oil in the outer container is so related to the position of the vent that the shell is always completely filled with oil regardless of the attitude of the package. The oil serves as a coolant for the tube and as insulation against corona and voltage breakdown for the transformer. Connecting leads through the shell employ insulation which swells in the oil automatically to provide sealing of the feed through holes.

Although the invention has been described as embodied in a specific assembly of a tube and transformer, many modifications will now occur to one skilled in the art, and other applications for a completely liquid-filled vented shell within a partially liquid-filled outer container will suggest themselves. It is the intention, therefore, that within the scope of the appended claims the invention may be practiced otherwise than as specifically illustrated and described.

What is claimed is:

1. For packaging an electronic assembly, a sealed outer container, an inner container, sealed except for a vent hole therein, supported within said outer container, and a liquid completely filling said inner container and partially filling said outer container to a level which insures immersion of said vent hole regardless of the attitude of said outer container.

2. For packaging a high voltage electronic assembly requiring insulation and cooling, a sealed outer container, an inner container formed of insulating material, sealed except for a vent hole therein, rigidly supported within said outer container, and a dielectric liquid completely filling said inner container and partially filling said outer container to a level which insures immersion of said vent hole regardless of the attitude of said outer container.

3. For packaging a high voltage electronic assembly requiring insulation and cooling and subject to a wide range of ambient temperatures, a sealed outer container, an inner container formed of insulating material rigidly supported within said outer container and spaced from all walls of the outer container, said inner container being sealed except for a vent hole therein, and a dielectric liquid completely filling said inner container and partially filling said outer container to a level which insures immersion of said vent hole regardless of expansion and contraction of said liquid with changes in ambient temperature over said range, and the attitude of said outer container.

4. A high voltage electronic assembly comprising, in combination, a sealed cylindrical outer container, an inner container formed of insulating material rigidly supported within said outer container nearer one end of said outer container than the other, said inner container being sealed except for a vent hole in a wall thereof confronting the more remote end of said outer container and located substantially on the longitudinal axis of said outer container, high voltage apparatus requiring insulation disposed within said inner container, apparatus requiring cooling disposed within said outer container and electrically connected to said high voltage apparatus, and a dielectric liquid completely filling said inner container and partially filling said outer container to a level which in-

sure immersion of said vent hole regardless of expansion and contraction of the liquid with changes in temperature, and the attitude of said outer container.

5. An electronic assembly comprising, in combination, a sealed cylindrical outer container having electrical terminals affixed to one of its end walls, a tube socket supported on said one end wall of said outer container coaxially within said outer container and electrically connected to said terminals, an electron tube in said socket, an inner container formed of insulating material and of smaller diameter than said outer container, means insulatingly supporting said inner container on said tube socket substantially coaxially with said outer container, a high voltage transformer supported within said inner container, connecting wires from said transformer to said tube socket, said inner container being sealed except for a vent hole in a wall thereof confronting said tube socket located substantially on the longitudinal axis of said outer container, and a dielectric liquid completely filling said inner container and partially filling said outer container to a level which insures immersion of said vent hole regardless of expansion and contraction of the liquid with changes in temperature, and the attitude of said outer container.

6. Apparatus in accordance with claim 5 wherein said dielectric liquid is silicone oil and said connecting wires extend through openings in the wall of said inner container having said vent hole, said wires having silicone rubber insulation which swells when immersed in silicone oil to seal said wires in said openings.

7. An electronic assembly package comprising, in combination, a sealed cylindrical outer container, external electrical connectors mounted on one end wall of said outer container, a tube socket supported within said outer container on said one end wall, a wiring network connected between said tube socket and said external connectors, an electron tube mounted on said tube socket coaxially with said outer container, an inner container formed of insulating material and of smaller diameter than said outer container, means insulatingly supporting said inner container on said tube socket, said inner container being sealed except for a central vent hole and feed-through holes for electrical leads in the wall thereof confronting said tube socket, a high voltage transformer mounted within said inner container, electrical leads having silicone rubber insulation thereon passing through said feed-through holes and connecting said transformer to said tube socket, and silicone oil completely filling said inner container and partially filling said outer container to a level which insures immersion of said vent hole regardless of expansion and contraction of said silicone oil with changes in temperature, and the attitude of said outer container, said silicone rubber insulation swelling when immersed in silicone oil to seal the feed-through holes in said inner container.

8. The apparatus of claim 7 wherein said inner container is formed of epoxy.

No references cited.